

DEPARTMENT OF COMMERCE AND LABOR

CIRCULAR

OF THE

BUREAU OF STANDARDS

S. W. STRATTON, DIRECTOR

No. 15

THE INTERNATIONAL UNIT OF LIGHT

[3d Edition]

Issued July 1, 1911



WASHINGTON
GOVERNMENT PRINTING OFFICE

1911

THE INTERNATIONAL UNIT OF LIGHT

The following announcement, relative to the unit of light of America, France, and Great Britain, was made in the first edition of this circular under date of April 1, 1909, and simultaneously in Great Britain and France. The announcement was made in Great Britain by Dr. R. T. Glazebrook, director of the National Physical Laboratory, and in France by Prof. Paul Janet, director of the Laboratoire Central d'Électricité.

* * * * *

ANNOUNCEMENT

“In order to determine as accurately as possible the relations between the photometric units of America, France, Germany, and Great Britain, comparisons have been made at different times during the past few years between the unit of light maintained at the Bureau of Standards, Washington; at the Laboratoire Central d'Électricité, Paris; at the Physikalisch-Technische Reichsanstalt, Berlin; and at the National Physical Laboratory, London.

The unit of light at the Bureau of Standards has been maintained through the medium of a series of incandescent electric lamps, the values of which were originally intended to be in agreement with the British unit, being made 100/88 times the Hefner unit.

The unit of light at the Laboratoire Central is the bougie décimale, which is the twentieth part of the standard defined by the International Conference on Units of 1884, and which is taken, in accordance with the experiments of Violle, as 0.104 of the Carcel lamp.

The unit of light at the Physikalisch-Technische Reichsanstalt is that given by the Hefner lamp burning at normal barometric pressure (76 cm) in an atmosphere containing 8.8 liters of water vapor per cubic meter.

The unit of light at the National Physical Laboratory is that given by the 10-candlepower Harcourt pentane lamp burning at normal barometric pressure (76 cm) in an atmosphere containing 8 liters of water vapor per cubic meter.

In addition to the comparisons of electric and flame standards carried out recently by the national laboratories in Europe, one comparison was made in 1906 and two in 1908 between the American and European units, by means of carefully seasoned carbon-filament electric standards, and as a result of all the comparisons, the following relationships are established between the above units.

The pentane unit has the same value within the errors of experiment as the bougie décimale. It is 1.6 per cent less than the standard candle of the United States of America and 11 per cent greater than the Hefner unit.

In order to come into agreement with Great Britain and France, the Bureau of Standards of America proposed to reduce its standard candle by 1.6 per cent, provided that France and Great Britain would unite with America in maintaining the common value constant, and with the approval of other countries would call it the International candle. The National Physical Laboratory, London, and the Laboratoire Central d'Électricité, Paris, have agreed to adopt this proposal in respect to the photometric standardization which they undertake, and the date agreed upon for the adoption of the common unit and the change of unit in America was April 1, 1909.

The following simple relations will therefore hold after that date:

- 1 international candle = 1 Pentane candle.
- 1 international candle = 1 Bougie Décimale.
- 1 international candle = 1 American candle.
- 1 international candle = 1.11 Hefner unit.
- 1 international candle = 0.104 Carcel unit.

Therefore 1 Hefner unit = 0.90 international candle.

The pentane and other photometric standards in use in America will hereafter be standardized by the Bureau of Standards in terms of the new unit. This, within the limits of experimental error, will bring the photometric units for both gas and electrical industries in America and Great Britain and for the electrical industry in France to a single value, and the Hefner unit will be in the simple ratio of 9/10 to the international candle.

The proposal to call the common unit of light to be maintained jointly by the national standardizing laboratories of America, France, and Great Britain, the "International candle" has been submitted to the International Electrotechnical Commission, which will endeavor to secure the indorsement of the proposal by all countries of the world which are represented on that commission.

It is hoped that such general approval may be secured, and that in the near future the term 'International candle' will receive general sanction."

STATEMENT

The following statement accompanied the formal announcement:

"The above announcement marks an important step forward in the history of photometric measurements. For many years the British parliamentary candle was the unit recognized in this country, but the lack of precision in practical photometry did not permit its value to be very accurately expressed or reproduced. In recent years the gas industry has

employed the 1-candlepower sperm candle, the 10-candlepower Harcourt pentane lamp, the Hefner lamp, and various secondary standards, while the electrical industry has employed incandescent electric lamps either certified by the Bureau of Standards or rated in terms of standards that are consistent with those of the bureau. The unit of the bureau has been maintained very constant, as shown by frequent comparisons with the standards of France, Germany, and Great Britain, but differed appreciably from the British unit and hence from the unit employed by most of the gas companies in America.

The Bureau of Standards took the initiative several years ago in bringing about international uniformity in the unit of light by sending its representatives abroad with copies of its standards to determine more accurately the relative values of the units of the several European countries and to urge the adoption of an international unit. In this country the American Institute of Electrical Engineers, the American Gas Institute, and the Illuminating Engineering Society have acted together in support of the movement, and have voted in advance to recognize the new unit of candlepower.

In England the National Physical Laboratory has secured the indorsement of the London Gas Referees and the Institution of Gas Engineers.

The union of the three national standardizing institutions of America, France, and Great Britain, in maintaining a common unit of candlepower, and the cooperation of the German Reichsanstalt in redetermining, from time to time, the ratio of the Hefner unit to the common international candle, assures the highest attainable constancy for the new unit of light.

Unfortunately there is no primary photometric standard that is sufficiently constant and reproducible from its specifications to be generally accepted as an international standard. France, Germany, and Great Britain each has its own primary flame standard, and a great deal of effort has been expended in attempting to determine accurately the relations between them. Until the flame standards themselves are better understood, however, and the atmospheric and other conditions more perfectly controlled, the unit of light can not be preserved as accurately by primary flame standards as by incandescent electric standards. The latter, when well made, properly seasoned, and carefully measured, permit comparisons to be made (using the means of many settings on several lamps) with excellent precision, the lamps themselves being constant enough and the precision of measurement high enough to fix the final values to about one or two tenths of 1 per cent. There is good reason to believe that in this way the international unit of light can be preserved so nearly constant that any inevitable drift occurring one way or the other would be too small to detect with certainty by any of our present flame standards in many years. The Bureau of Standards will continue to standardize flame standards by the electric standards and will also carefully investigate the more important flame standards. Similar tests and investigations will also be made in Europe, and if any appreciable drift does occur it will sooner or later be detected.

Careful distinction should be made in this connection between a *unit* and a *standard*. An international unit maintained by the cooperative effort of several national standardizing institutions, and checked from time to time by means of all the best primary standards in use, is more likely to be maintained constant than if it were defined to be represented by any single primary standard, unless such a primary standard were reproducible to a very high degree of precision. Such a *unit* can be continued permanent even though all present primary *standards* are ultimately superseded by better ones. The Hefner lamp as a convenient flame *standard* will not be displaced in America or any other country which adopts the international candle as its unit of light. Uniformity among different countries and continuity of value are prime necessities with respect to the *unit*. But the particular standard by which the unit is realized in practice is largely a matter of convenience and circumstance. In the photometry of electric lamps, electric standards are most suitable. In gas photometry one form of flame standard or another will be employed, according to circumstances. It is not expected that all countries of the world will at once adopt the proposed international candle as their unit of light. Those countries which already have the Hefner unit in general use may prefer to continue it. But if all countries which have a unit differing appreciably from the Hefner shall adopt the international candle as their unit, there will then be only two units in use throughout the world, and they will have the simple ratio 9 : 10. This would result in a distinct gain both in the practice of photometry and in definitions and nomenclature.

The effect of this change of 1.6 per cent in the unit of the bureau, which is in general use for electric lighting throughout the country, is to raise the candlepower rating and decrease slightly the watts-per-candle of electric lamps. A 16-candlepower lamp will give 16.26 candles in the new unit, or a 16-candlepower carbon-filament lamp burning at 110 volts will give 16 candles on the new basis at 109.69 volts. The change, though small, is important in the photometry and rating of lamps.

The new unit of candlepower being in agreement with the present English unit as represented by a 10-candlepower standard pentane lamp, there will be no change in the unit of light now employed by those gas companies which use pentane lamps, provided they are in agreement with the English standard.¹ But as pentane lamps may differ slightly from one another, even when burned under the same conditions, it is desirable for the sake of greater uniformity to have them standardized in terms of the standard candle of the bureau. These variations, amounting to from 1 to 5 per

¹ As stated above, this change of 1.6 per cent is not a change of the British standard candle, but represents the difference between the value of that unit as accepted in England and the value which was assigned as a result of experiments in Germany. The latter value, 100/88 times the Hefner unit, was accepted by the American Institute of Electrical Engineers as the best one available at the time and later became the basis of the old Bureau of Standards candle. While this was intended to be equivalent to the British unit, exact agreement was not to be expected for the double reason that sperm candles are essentially variable and that the German investigators obtained their value by using a fixed flame height, whereas the English custom has always been to specify the rate of consumption of sperm.

cent, are generally in the same direction; that is, the lamps if not correct usually give less than 10 international candles under standard conditions when burning in a pure atmosphere at a normal barometric pressure of 76 centimeters of mercury and an atmospheric humidity of 8 liters of water vapor per cubic meter. In anticipation of this change some of the largest gas companies in the United States have already had their pentane and Hefner standard lamps standardized by the bureau in terms of the new unit.

Gas standards will hereafter be certified in terms of the international candle. Electric standards will be certified in terms of the old unit until July 1, 1909, unless otherwise requested. On July 1, the new unit will be adopted by the Bureau of Standards in the certification of electric standards, and it is hoped that manufacturers of electric lamps will adopt the new unit as soon thereafter as possible.

The bureau recommends that all gas and electric companies, all photometric laboratories, and all the manufacturers of electric lamps in the United States adopt the new unit of candlepower, if possible, not later than January 1, 1910.

Further information with regard to change of photometric unit or to the testing of gas and electric standards will be given on request."

* * * * *

It is now two years since the new unit of candlepower was adopted, and during that time it has become general in this country. The bureau has carried on an investigation of photometric flame standards during these two years, and continued its investigation of carbon-filament lamps as photometric standards. The results have confirmed the position taken by the bureau two years ago in holding that the international candle can be maintained by means of carbon-filament lamps used as primary standards probably more accurately even for quite long intervals of time than by the use of any flame standards so far employed.

S. W. STRATTON,
Director.

Approved:
BENJ. S. CABLE,
Acting Secretary.



